

## APPARATUS FOR REDUCING THE DIAMETER OF A STENT

### BACKGROUND OF THE INVENTION

**[0001]** The invention relates to an apparatus for reducing the diameter of a stent.

**[0002]** Such an apparatus belongs to the state of the art in view of the DE 297 14 857 U1. It includes a clamping tongs with arms movable relative to one another and configured with conical openings. The openings expand towards the central transverse plane of the clamping tongs.

**[0003]** The apparatus further includes a shaping body for a stent which can be received in the openings of the clamping tongs, i.e. the stent includes a short central portion, which is continued by two conically descending portions in a direction of the end surfaces, and two cylindrical end portions. The shaping body has a central passageway for receiving a stent.

**[0004]** The shaping body is subdivided in radial direction by several longitudinally extending slots to define interconnected compressors. The cross section of the compressors is wedge-shaped, with the compressors narrowing in a direction of the center axis of the shaping body.

**[0005]** The known apparatus requires manual adjustment of an adjustment screw at the arms of the clamping tongs in order to reduce the diameter of the stent. Errors as a result of human inadequacy cannot be avoided hereby. As stents are typically placed upon catheters and the stents as well as the catheters have tolerances, it becomes difficult to attain a consistent result, each time the diameter of a stent is to be reduced (crimped). In addition, the known apparatus enables to date a reduction in diameter of a stent only along its entire length by a same amount. It is not possible to tailor individual sections of length portions for a

reduction in diameter.

**[0006]** US 6,629,350 B2 discloses a further apparatus for crimping of stents. Stents are placed in a cylindrical opening in the front side of this apparatus. By actuating a lever on the right side by means of a further device, the radius of the cylindrical opening is reduced via a mechanism and the stent compressed. In this way, the stent is compressed evenly. The degree of compression can be set accurately and is reproducible.

**[0007]** A drawback of this apparatus is the fact that stents of only up to a defined length can be placed in it and that the compression of the stent can be evenly compressed only along the entire length.

#### SUMMARY OF THE INVENTION

**[0008]** Originating from the state of the art, the invention is based on the object to provide an apparatus for reducing the diameter of a stent which apparatus attains at all times an exactly reproducible result and further allows a reduction in diameter of desired individual length portions of a stent.

**[0009]** The object is attained by an apparatus which includes compressors which act, at least indirectly, radially on the outer surface of the stent and are supported on a circumferential abutment, wherein flexible tensioning members are provided between the radially inwardly moving segmental compressors and the abutment and actuatable by a pressure fluid in opposition to a resiliently elastic rebound force.

**[0010]** The basic idea of the invention is the use of a pressure fluid (compressed air or pressure liquid) which can be adjusted precisely and reproducibly to the respectively desired and required pressure level. The pressure fluid is received in flexible tensioning members which are arranged between

radially inwardly movable segmental compressors and an abutment disposed circumferentially about the compressors. When the tensioning members are acted upon by the pressure fluid, the compressors shift radially inwards while being supported on the abutment and reduce the diameter of a stent precisely to the extent, as desired.

**[0011]** In this context, the invention also allows to subject the circumference of a stent, at least indirectly, to different pressures. In other words, a stent is subjected for example to a certain pressure on opposite circumferential sections by tensioning members provided there, while a different pressure is applied on the other circumferential sections. In this way, certain ovality may be imparted upon the stent.

**[0012]** The invention provides the conditions for a stent as such to be reduced (crimped) in diameter and to be placed subsequently upon a catheter. The invention allows however in addition to press a stent directly upon a catheter. The invention is especially advantageous when used for stents coated with medicaments. As in such a case, the medicament-coated stent is surrounded by a tube as protective envelope, the apparatus according to the invention is prevented from damaging the medicament coating. When properly securing the stent upon a catheter, the tube can then easily be removed.

**[0013]** The resiliently elastic rebound force provides a return of the compressors to their initial position, once the pressure in the tensioning members is relieved so that the treated stent can be removed from the apparatus together with a catheter if necessary.

**[0014]** As the radial displacement of the compressors involve only limited distances, it is of advantage to form the tensioning members as balloons or expandable tubes.

**[0015]** A preferred incorporation of the tensioning members in the apparatus according to the invention is realized when the compressors have concave contact surfaces in a direction towards the circumferential abutment and the abutment has concavely curved resistance surfaces which are open towards its center axis. Contact surfaces and resistance surfaces then form for the tensioning members circumferentially virtually closed chambers in which the tensioning members expand when subject to a pressure fluid so that the compressors are able to move radially inwards while supported on the abutment.

**[0016]** According to another advantageous feature of the invention, the compressors are disposed in at least two planes in parallel relationship and radially movable in each plane independently of the compressors in a neighboring plane. Such an embodiment allows, regardless of the number of planes, to move the compressors in predetermined planes more or less severe in relation to the neighboring compressors. In this way, different crimp configurations can be realized over the length of a stent. When ball catheters are involved for example, it is oftentimes suitable to crimp a stent to a greater extent at the ends than in the central length portion.

**[0017]** Different pressures can be applied to a stent also in this embodiment - as viewed across the circumference. These pressure conditions are, however, preferably always identical in the different planes.

**[0018]** The axial length of the planes can be selected differently in dependence on the respective demands. The abutment extends then preferably across all planes.

**[0019]** According to another feature of the invention, it is of advantage that the compressors respectively embrace a radially inwardly directed strut of the cylindrically configured abutment and are supported upon the strut in a resiliently elastic manner. The resiliently elastic support thus continually ensures the starting

position in which a stent can be inserted in the apparatus or removed from the apparatus. On the other hand, the struts provide an exact guidance of the compressors in radial direction. Tilting and wedging are hereby eliminated.

**[0020]** In this context, a preferred embodiment is characterized in accordance with another feature of the invention by configuring the compressors as hollow circular segments which have radially directed diverging legs and projections pointing toward one another adjacent to the abutment for direct support upon the struts and inwardly directed spring tongues for support upon crossbars of the struts.

**[0021]** This embodiment thus involves a stent to be deformed having circumferentially several, for example eight or twelve, compressors with a configuration in the form of a pie slice which are as such radially displaceable by the tensioning members between the compressors and the struts on the abutment. The portions, which form the resistance surfaces on the struts and are thickened by material, directly contact the diverging legs of the compressors. The legs of the compressors are provided at the radially outer end with projections, optionally arranged in pairs, which point to one another. This ensures the exact radial displacement capability. The inwardly directed spring tongues at the legs of the compressors have, preferably, a slightly arched contour and rest against the crossbars of the struts at their sides facing the circumferential abutment. These spring tongues thus provide that the compressors are in effect biased continuously in the direction of the abutment. Their spring force can be overcome by the pressure fluid in the tensioning members.

**[0022]** In this embodiment, the compressors as well as also the abutment may be formed of a metal, in particular steel. Preferred however is the use of a suitable plastic for the compressors, whereas the abutment is made of special steel.

**[0023]** According to another feature of the invention, the compressors are part of a metallic spring band which extends in circumferential direction in the form of a meander and has trapezoidal zones for respective support on two neighboring struts of the abutment made of a metal.

**[0024]** The elasticity of the spring band is hereby such that the trapezoidal zones between two circumferentially adjacent struts of the abutment are braced in a wedge-shaped manner, when the tensioning members are acted upon by pressure. When the pressure is subsequently relieved in the tensioning members, the restoring force inherent in the trapezoidal zones causes the compressors to again move radially outwards and to liberate the deformed stent.

#### BRIEF DESCRIPTION OF THE DRAWING

**[0025]** Exemplified embodiments of the invention will now be described in more detail with reference to the drawings, in which:

**[0026]** Fig. 1 shows a schematic perspective illustration of an apparatus for reducing the diameter of a stent;

**[0027]** Fig. 2 shows a plan view of the apparatus of Fig. 1;

**[0028]** Fig. 3 shows a plan view of a detail of the apparatus of Figs. 1 and 2;

**[0029]** Fig. 4 shows a plan view of a further detail of the apparatus of Figs. 1 and 2;

**[0030]** Fig. 5 shows a plan view of a further embodiment of an apparatus for reducing the diameter of a stent;

**[0031]** Fig. 6 shows a plan view of a detailed portion of the apparatus of Fig. 5;

**[0032]** Fig. 7 shows a plan view of a further detail of the apparatus of Fig. 5; and

**[0033]** Fig. 8 shows a plan view of a further embodiment of an apparatus for reducing the diameter of a stent.

#### DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS

**[0034]** An apparatus for reducing the diameter of a stent 2, not shown in greater detail, is labeled in Figs. 1 and 2 with 1.

**[0035]** According to Figs. 1 to 3, the apparatus includes a cylindrical abutment 3 of steel. Extending radially inwards from the inner surface 4 of the abutment 3 are struts 5 which have open concave cylinder segment like resistance surfaces 8 at the inner wider end 6 toward the center axis 7.

**[0036]** As can be seen in Figs. 1 to 3, the abutment 3 with the struts 5 is coupled with segmental compressors 9 by being moved axially into one another (Figs. 1, 2 and 4) which form components of a spring band 10 extending in the form of a meander in circumferential direction. The compressors 9 have legs 11 diverging from the center axis 7. Adjacent to the center axis 7, the compressors 9 are strengthened by material and provided with oblong holes 12. The neighboring legs 11 of each two compressors 9 merge at the radially outer ends into trapezoidal zones 13 which, as can be seen in Figs. 1 and 2, are able to support upon neighboring struts 5 of the abutment 3.

**[0037]** The compressors 9 are provided in confronting relationship to the resistance surfaces 8 on the wider ends 6 of the struts 5 with contact surfaces 14

which extend concavely in relation to the trapezoidal zones 13 and have a curvature in correspondence to the curvature of the resistance surfaces 8.

**[0038]** As shown in Figs. 1 and 2, the contact surfaces 14 and the resistance surfaces 8 form cylindrical receiving zones for placement of the flexible tensioning members 15 in the form of tubes (Fig. 2). These tensioning members 15 can be acted upon by a pressure fluid in the form of compressed air or a pressure liquid. The tubes have been omitted in Fig. 1.

**[0039]** According to the illustrations of Figs. 1, 2 and 4, the end surfaces 16 of the compressors 9 in confronting relationship to the center axis 7 form in the center a receiving zone for a stent 2. This receiving zone may be sized large enough to allow insertion of a catheter with attached stent 2.

**[0040]** In order to reduce the diameter of the stent 2, i.e. to press the stent 2 onto a catheter for example, the tensioning members 15 are acted upon by pressure fluid. As a result, the compressors 9 are moved radially inwards while being supported on the struts 5 and the stent 2 is pressed onto the catheter.

**[0041]** After relieve of the pressure in the tensioning members 15, the trapezoidal zones 13 cause again as a consequence of their configuration in concert with the material of the spring band 10 as well as the struts 5 adjacent to the trapezoidal zones 13 a displacement of the compressors 9 radially outwards in the direction of the abutment 3 to assume the ready position.

**[0042]** As can be seen from Fig. 1, a single cylindrical abutment 3 may accommodate several meandering spring bands 10 stacked above one another in parallel lanes E, E1 etc. In such a case, it is then possible to arrange in each plane E, E1 etc. tensioning members 15 in the form of balloons for example between the contact surfaces 14 on the compressors 9 and the opposite resistance surfaces 8, which tensioning members can be acted upon by pressure



fluid in a desired manner. In this way, it is possible, to reduce the diameter of a stent 2 in certain sections, e.g. as is suitable at the end portions of balloon catheters.

**[0043]** The apparatus 1a shown in Figs. 5 to 7 for reducing the diameter of a stent 2 has again a cylindrical abutment 3a from which struts 5a extend out in the direction of the center axis 7a. Also this abutment 3a and the struts 5a are made of steel.

**[0044]** As shown in particular in Fig. 7, the struts 5a include approximately in the middle length portion laterally projecting crossbars 17. The wider ends 6a of the struts 5a in the direction of the center axis 7a have cylinder segment like convex resistance surfaces 8a like in the embodiment of Figs. 1 to 4.

**[0045]** The struts 5a according to Figs. 5 and 7 are coupled with segmental compressors 9a of plastic which are configured as hollow circular segments (Figs. 5 and 6).

**[0046]** The compressors 9a have legs 11a which diverge from the ends 18, strengthened by material adjacent to the center axis 7a. Provided at the ends 19 of the legs 11a are projections 20 arranged in parallel relationship and extending towards one another. These projections 20 provide a guidance of the compressors 9a on the struts 5a jointly with the legs 11a and the neighboring ends 6a of the struts 5a.

**[0047]** Moreover, the compressors 9a adjacent to the projections 20 have inwardly directed arched spring tongues 21 which, as can be seen from Fig. 5, are supported on the sides 22 of the crossbars 17 of the struts 5a in confronting relationship to the circumferential abutment 3a. As a result of the resiliently elastic rebound force of the spring tongues 21, the compressors 9a are thus biased in the direction of the abutment 3a.

**[0048]** Adjacent to the strengthened zones 18 of the compressors 9a, the latter have concave contact surfaces 14a which complement the concavely curved resistance surfaces 8a. Like in the embodiment of the apparatus according to Figs. 1 to 4, the contact surfaces 14a and the resistance surfaces 8a form receiving zones for flexible tensioning members 15, for example in the form of tubes acted upon by pressure fluid.

**[0049]** When the tensioning members 15 are acted upon by a pressure fluid (compressed air or pressure liquid), the compressors 9a are displaced radially inwards while supported on the struts 5a and reduce in this way the diameter of a stent 2 disposed in the central receiving zone at the end of the compressors 9a, optionally by being pressed upon a catheter not shown in greater detail.

**[0050]** After removing the pressure in the tensioning members 15, the spring tongues 21 on the compressors 9a cause the compressors 9a to move radially outwards again to assume the ready position.

**[0051]** Also the apparatus 1a can have compressors 9a in several planes E, E1 etc, as has been explained with reference to Fig. 1.

**[0052]** The apparatus 1 shown in Fig. 8 illustrates a further embodiment. Fig. 8 differs from Fig. 2 by the increased number of segments and by the configuration in this figure of the oblong holes 12 of Fig. 2 as triangular apertures 23.

**[0053]** The remaining reference signs have been used identically so that a further description is not necessary.